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浙江安吉志留纪真盔甲鱼类一新属[1)]

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摘要: 记述了浙江安吉地区志留纪真盔甲鱼类一新属——安吉鱼(新属)(*Anjiaspis* gen. nov.)。新属的主要特征是:中背孔呈纵长的滴水形,前端稍尖,距离头甲吻缘较远,后端圆钝,明显位于两眶孔前缘连线之前;眶孔较小,位置十分靠近头甲中线,并距离头甲后缘较近,眶孔前区长于眶孔后区;松果孔大致位于两眶孔中心连线上;感觉管系统大致呈格栅状分布,可见4条纵行干管及联络它们的横行管,横行管由侧横管和中横联络管组成,其数目均比较多;鳃囊6对,纹饰为均匀分布的细小粒状瘤点。在此基础上运用分支系统学的方法对其系统位置进行了探讨,结果表明,新属代表了真盔甲鱼类的最原始类型。

关键词: 浙江安吉,志留纪,真盔甲鱼类

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1 前言

浙江西北部的志留系以安吉地区最为发育。该系在安吉地区发育完整,出露较多,自下而上可划分为安吉组、大白地组、康山组和茅山组。下部安吉组为浅海—海岸带碎屑岩沉积,岩性为粉砂质泥岩,粉砂岩夹细砂岩,含有 *Glyptograptus persculptus* 和 *Akidograptus ascensus* 两个笔石带;中下部大白地组为海岸相碎屑岩沉积,岩性以粉砂至细砂岩为主夹泥岩,含腕足类 *Eospirifer uniplicatus*、*E*. aff. *E*. *maiatus*、*Fardenia* sp.、*Zygospira* sp.等;中部康山组在安吉地区以海滩—潮坪相砂泥岩为主,含腕足类 *Eospirifer* sp.、*E*. *uniplicatus*、*Resserella* sp.、*Dalmanella cimex*、*Plectodonta* sp.;三叶虫 *Encrinuroides* sp.、*Coronocephalus res*;腹足类 *Lophospira* sp.及珊瑚、头足类、海百合茎等。上部茅山组为三角洲—河流相碎屑岩沉积,岩性为灰绿色、紫红色岩屑石英砂岩夹少量泥质粉砂岩,含少量鱼类和腕足类(浙江省地质矿产局,1989)。茅山组在长兴地区目前已有大量无颌类化石发现,计3属3种,分别为浙江"中华盔甲鱼"('*Sinogaleaspis*' *zhejiangensis* Pan, 1986)、雷曼煤山鱼(*Meishanaspis lehmani* Wang, 1991)和顾氏长兴鱼(*Changxingaspis gui* Wang, 1991)。但在安吉地区该组却一直未见可鉴定属种的无颌类化石的报道。潘江(1986)报道在安吉古城、栾家坞一带发现真盔甲鱼类和中华棘鱼的棘刺化石,但未进行古生物学描述。

2004年春,笔者按潘江先生记述的地点,在安吉古城一带对茅山组开展野外调查,在

1) 国家自然科学基金重点项目(编号:40332017)、国家重点基础研究发展规划项目(编号:G2000077704)和国家基础科学特殊学科点人才培养基金资助。

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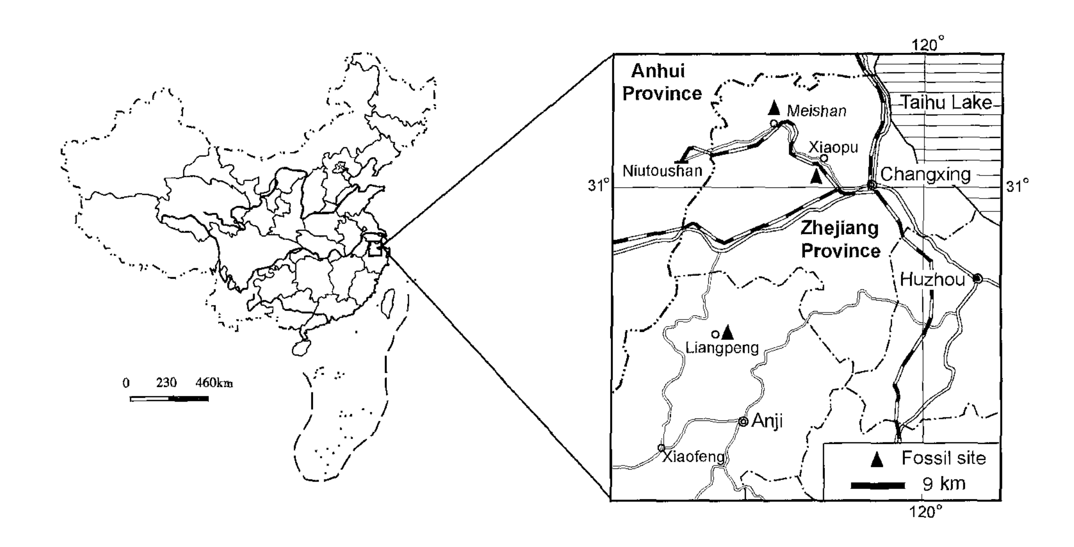


图 1 浙江西北地区早期脊椎动物化石分布

Fig. 1 Fossil localities of early vertebrates in northwestern Zhejiang, China

良朋附近一采石场(图 1)发现一无颌类不完整的头甲。由于化石材料比较破碎,当时并没有做出属种鉴定。2004 年底,笔者再次赴该地区采集化石,终获一完整的头甲。经室内鉴定为真盔甲鱼类的一新属,现将标本记述如下。

2 标本记述

盔甲鱼亚纲 Galeaspida Tarlo, 1967

真盔甲鱼目 Eugaleaspiformes (Liu, 1965) Liu, 1980

安吉鱼(新属) *Anjiaspis* gen . nov.

(图 2 ~ 5)

词源 从产地,Anji 安吉,aspis (Gr.)盾甲。

属型种 网状安吉鱼(新属、新种) *Anjiaspis reticularis* gen. et sp. nov.。

属征 个体较小的真盔甲鱼。头甲呈横宽的三角形,边缘呈锯齿状;角和内角不甚发育,呈短棘状;中背孔呈纵长的滴水形,前端稍尖,距离头甲吻缘较远,后端圆钝,明显位于两眶孔前缘连线之前;眶孔较小,位置十分靠近头甲中线,并距离头甲后缘较近,眶孔前区长于眶孔后区;松果孔大致位于两眶孔中心连线上;感觉管系统呈格栅状分布,可见 4 条纵行干管及联络它们的横行管,横行管由侧横管和中横联络管组成,数目均较多;鳃囊 6 对,纹饰为均匀分布的细小粒状瘤点。

比较与讨论 新属以纵长的中背孔及"真盔甲鱼"型侧线系统等显著特征而归入真盔甲鱼目(朱敏,1992;盖志琨等,2005)。新属眶孔较小,位置显著靠近头甲中线,这可以与真盔甲鱼目其他属种明显区分。就头甲形状而言,新属与雷曼煤山鱼及西坑"中华盔甲

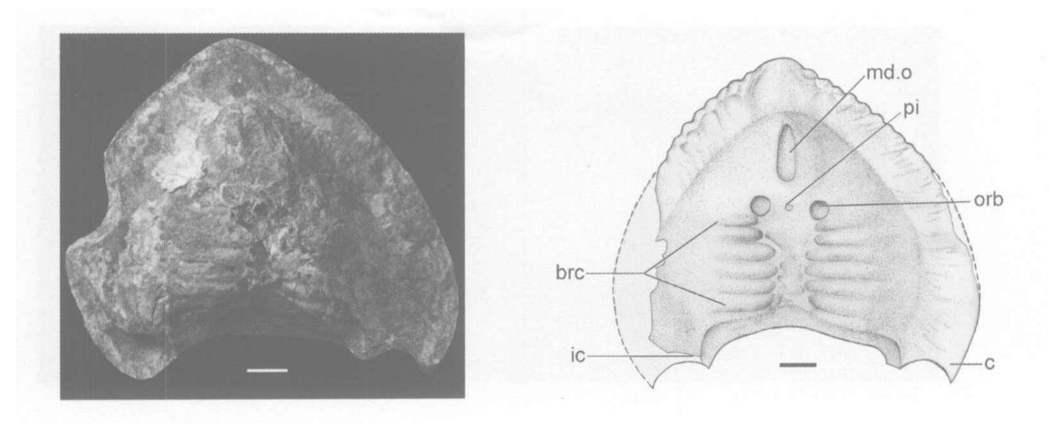


图 2 网状安吉鱼(新属、新种)头甲(IVPP V 14332.1,正型标本),比例尺 = 2 mm
Fig. 2 The cephalic shield of *Anjiaspis reticularis* gen. et sp. nov. (IVPP V 14332.1, Holotype) scale bar = 2 mm
简字说明 Abbreviations: brc. branchial chamber 鳃囊; c. corner 角; ic. inner corner 内角; md.o. median dorsal opening 中背孔; orb. orbital opening 眶孔; pi. pineal opening 松果孔

鱼”(‘*Sinogaleaspis*’ *xikengensis* Pan et Wang, 1980)最为接近,均呈横宽的三角形,且头甲边缘具有特殊的锯齿状构造(根据笔者的重新观察,西坑“中华盔甲鱼”的头甲边缘亦呈锯齿状),但新属的角和内角均很小,呈短棘状,而后两者的角和内角均很发育。就中背孔的形状和松果孔的位置而言,新属与西坑“中华盔甲鱼”更为相似,二者的中背孔均呈后端圆钝,前端稍尖的滴水形,且后端和眶孔前缘连线之间还有一段距离。二者的区别在于西坑“中华盔甲鱼”的中背孔前端已经抵达吻缘,而新属中背孔的前端离头甲吻缘还有较远的一段距离。雷曼煤山鱼的中背孔呈两端稍尖的狭长椭圆形,前端抵达吻缘,后端与两眶孔前缘连线齐平,与新属也很容易区分。在松果孔位置方面,新属与西坑“中华盔甲鱼”的松果孔大致位于两眶孔的中心连线上,而雷曼煤山鱼的松果孔则大致与两眶孔的后缘连线齐平。

就头甲的形态特征而言,新属表现出许多与真盔甲鱼目外类群相似的特征,如头甲边缘呈现锯齿状,眶孔位置靠近头甲中线等,这些特征在外类群湖南大庸鱼(*Dayongaspis hunanensis* Pan et Zeng, 1985)中同样存在,可能为近祖性状。

在感觉管系统方面,新属与现有的真盔甲鱼类各属也有较大的差异。新属头甲背面可见 4 条纵贯头甲的纵行干管及 8 条与之相联络的横行管(图 3B、4、5)。4 条纵行干管呈左右对称分布,外侧的 2 条为眶下管和侧背管,眶下管向前延伸至中背孔前端;中间的 2 条可能与真盔甲鱼类中广泛存在的前眶上管、后眶上管及中背管相当,但在新属中 3 者是自然衔接在一起的,并没有断开或交角现象。横行感觉管方面,新属以数目众多的中横联络管与盔甲鱼类的其他属种明显区分。在已发表的盔甲鱼类中,山口中华盔甲鱼(*Sinogaleaspis shankouensis* Pan et Wang, 1980)的中横联络管数目被认为是最多的,为 3 条。但在新属中,中横联络管的数目却多达 8 条,除了具有可能与之对应的 3 条以外,在新属

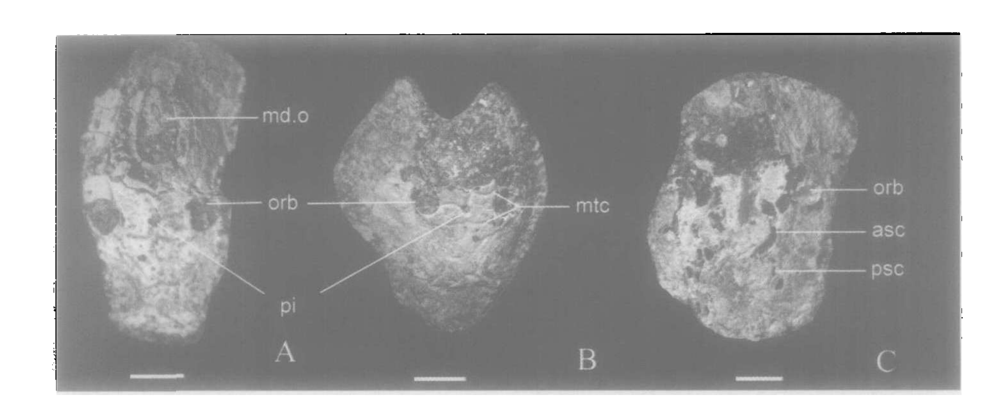


图3 网状安吉鱼(新属、新种)的头甲,比例尺=2 mm

Fig. 3 The cephalic shield of *Anjiaspis reticularis* gen. et sp. nov., scale bar = 2 mm

A, B. 一不完整头甲的外模(A)与内模(B) external (A) and internal (B) moulds of an incomplete cephalic shield (V 14332.3A, B); C. 一不完整头甲的内模 internal mould of an incomplete cephalic shield (V 14332.2A)

简字说明 Abbreviations: asc. anterior semicircular canal 前半规管; md.o. median dorsal opening 中背孔; mtc. median transverse canal 中横联络管; orb. orbital opening 眶孔; pi. pineal opening 松果孔; psc. posterior semicircular canal 后半规管

的眶孔后缘、中心、前缘及中背孔后缘等水平位置上,都有中横联络管的分布。总之,新属感觉管的这种分布格局最为接近刘玉海(1986)所设想的原始脊椎动物的侧线系统的分布格局。刘玉海(1986)认为原始脊椎动物的侧线系统分布格局呈格栅状,即由纵行干管和联络这些纵行管的横行管组成。而横行感觉管的分布,刘氏认为在原始脊椎动物中很可能是按节排列,由前而后分布整个头区,只是由于眼、鼻等感觉器官的存在,这种排列在眶孔之前的部分受到了干扰。从新属来看,这种排列方式却并没有受到太大的干扰,在新属的眶孔后缘、中心、前缘及中背孔后缘等水平位置上均可见间隔均匀的横行管分布。

鉴于以上的比较与讨论,笔者认为网状安吉鱼的属征明显,容易与其他真盔甲鱼类区分,所以新属新种成立。

网状安吉鱼(新种) *Anjiaspis reticularis* gen. et sp. nov.

词源 *reticularis*, 网状的,表示该鱼的感觉管系统呈格栅状或网格状分布。

正型标本 1件比较完整的头甲。中科院古脊椎所标本登记号 IVPP V 14332.1。

归入标本 2件不完整头甲的内外模,IVPP V 14332.2A,B、14332.3A,B。

产地与层位 浙江安吉,志留纪温洛克世茅山组。

种征 同属征(惟一的种)。

描述 个体较小的真盔甲鱼,头甲呈横宽的三角形,边缘具整齐的锯齿状构造。正型标本(V 14332.1)的头甲长约19 mm,宽约21 mm,中长约15 mm,其宽稍大于长。头甲背面沿中轴线显著隆起,侧缘较为平坦,吻缘向前较为突出(图2,5;表1)。

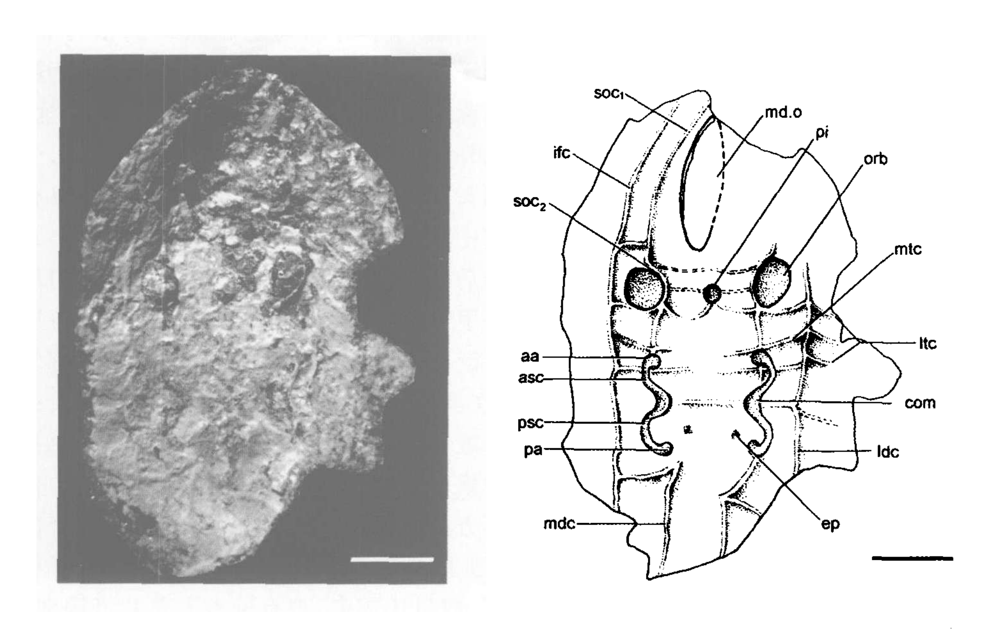


图 4 网状安吉鱼(新属、新种)头甲外模(IVPP V 14332.2B),比例尺 = 2 mm

Fig. 4 External mould of the cephalic shield of *Anjiaspis reticularis* gen. et sp. nov. (IVPP V 14332.2B), scale bar = 2 mm

简字说明 Abbreviations: aa. anterior ampulla 前半规管的壶腹; asc. anterior semicircular canal 前半规管; com. commissural division of anterior and posterior semicircular canals 前后半规管的联合部; ep. endolymphatic pore 内淋巴孔; ifc. infraorbital canal 眶下管; ldc. lateral dorsal canal 侧背管; ltc. lateral transverse canal 侧横管; mdc. median dorsal canal 中背管; md.o. median dorsal opening 中背孔; mtc. median transverse canal 中横联络管; orb. orbital opening 眶孔; pa. posterior ampulla 后半规管的壶腹; pi. pineal opening 松果孔; psc. posterior semicircular canal 后半规管; soc_1. anterior supraorbital canal 前眶上管; soc_2. posterior supraorbital canal 后眶上管

角和内角不甚发育,呈短棘状,外角稍大于内角,2 个内角的间距约 11 mm (图 2,5;表 1)。

中背孔呈后端圆钝、前端稍尖的滴水形,长约 3.5 mm,宽约 1 mm,长宽比率约为 3.5。中背孔前端距离头甲吻缘较远,之间距离约为 4 mm,后端明显位于两眶孔前缘连线之前(图 2,3A,5;表 1)。

眶孔圆形,较小,直径约 1.1 mm,约占整个头甲中长的 1/14,眶孔位置十分靠近头甲中线,两个眶孔的内间距约 1.9 mm,占整个头甲中长的 2/15 左右,远远小于真盔甲鱼目的其他属种;另外眶孔中心距离头甲后缘较近,其中心连线距头甲吻缘和后缘的距离分别为 9 mm 和 6 mm,眶孔前区长于眶孔后区(图 2,3A ~ B,5;表 1)。

松果孔的位置比较靠前,大致位于两眶孔的中心连线上,松果孔前区大于松果孔后区(图 2,3A ~ B,5)。

标本 V 14332.2A,B 和 V 14332.3A,B 分别保存了部分感觉管系统,可以补充正型标本的一些不足。新属的感觉管系统大致呈格栅状分布。标本 V 14332.2B 上可见 4 条纵

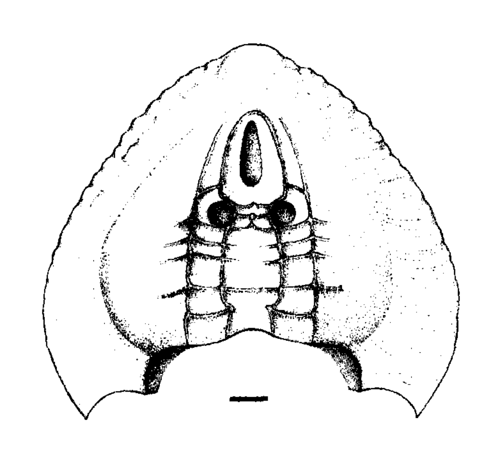


图5 网状安吉鱼头甲复原,背视,比例尺 = 2 mm

Fig. 5 Restoration of the cephalic shield of *Anjiaspis reticularis*, dorsal view, scale bar = 2 mm

贯头甲的纵行干管和与之相联络的横行管。4条纵行干管呈左右对称分布,外侧的2条为眶下管和侧背管,眶下管起始于中背孔前端不远处,沿眶孔外侧向后延伸,与侧背管自然衔接,一直延伸到头甲后缘(图3A,4)。中间的2条纵行管前端在中背孔前缘自然衔接(图3A),沿中背孔两侧向后逐渐扩展,经过眶孔内缘,一直向后延伸至头甲后缘。该2条平行管可能与真盔甲鱼类中广泛存在的前眶上管、后眶上管及中背管相当,但在新属中3者是自然衔接在一起的,并没有断开或交角现象(图4)。横行感觉管包括侧横管和中横联络管。侧横管保存不完全,仅右侧眶孔右下方的侧背管上保存了3条长度较短的侧横管(图4)。中横联络管为连络4条纵行干管的横向管,数目比较多,现有标本上总共可辨别出8条,除了在眶孔后区的头甲上有分布以外,在眶孔的后缘、中心、前缘及中背孔后缘的水平位置上均有所分布。8条中横联络管大致平行排列,与4条纵行管组成若干小格栅(图3B,4,5)。由于新属的侧横管保存不完全,所以在8条中横联络管中,哪一条与盔甲鱼类中广泛存在的背联络管相当,目前尚不清楚。

标本V 14332.2B除保存了新属的感觉管系统以外,还保存了耳区半规管的印痕。在镜下前后半规管及其壶腹均清晰可见,呈一对侧位的"W"形,相对排列在头甲中线附近,位置与中间2条纵行管有所重叠,遮住了2条纵行管的中间部分。在后半规管内侧的头甲上,还有2个洞穿背甲的小孔清晰可见。该对构造在顾氏长兴鱼中首次发现,被解释为内淋巴管的外开孔(图3C,4)。

表1 网状安吉鱼(新属、新种)正型标本的测量

Table 1 Measurements of *Anjiaspis reticularis* gen. et sp. nov. (Holotype) (mm)

最大长(maximum length of shield)	19
最大宽(maximum breadth of shield)	21
中长(length of shield in mid-line)	15
眶孔直径(diameter of orbital opening)	1.1
眼间距(distance between orbital openings)	1.9
眶孔前后距中长比(ratio between pre-orbital length and postorbital length in mid-line)	1.5
中背孔长(length of median dorsal opening)	3.5
中背孔宽(breadth of median dorsal opening)	1
中背孔前端至吻端长(length from anterior end of median dorsal opening to rostral end)	4
中背孔后端至头甲后缘中点长(length from posterior end of median dorsal opening to midpoint of posterior margin of shield)	7.5
内角间距(distance between inner corners)	11

鳃囊 6 对,与中线呈垂直排列,其中第一对鳃囊起始于眶孔后缘,最后一对鳃囊紧贴头甲后缘(图 2)。

纹饰为细小的粒状突起,分布非常均匀,与浙江中华盔甲鱼的纹饰较为相似。

测量　见表 1。

3　系统位置讨论

在盖志琨等(2005)对整个真盔甲鱼目系统发育分析的基础上,将新属特征置于新的性状矩阵中(Appendix I,II)进行系统发育分析。因新属的眶孔位置较其他真盔甲鱼类明显靠近头甲中线,与外类群比较相似,所以在新的性状矩阵中增加一新性状。

24.眶孔位置:0. 相对靠近头甲中线位置;1. 距头甲中线相对较远。

系统分析的数据处理利用 PAUP 3.1.1 程序,采用最简约法,在 Macintosh 上运行。计算时除了性状(4)为有序(ordered)外,其余所有性状均为"无序(unordered)"和"等权"处理,用分枝一界限搜索(branch-and-bound search),共得到 3 个最简约的分支树及它们的严格合意树(图 6),其树长(Tree length) = 44,一致性指数(CI) = 0.659,保留指数(RI) = 0.817。

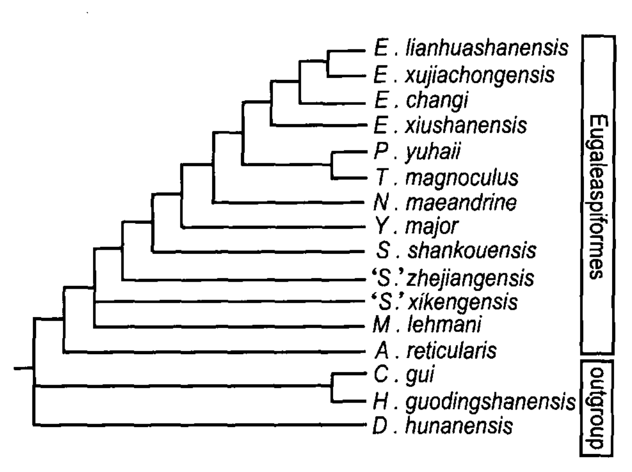


图 6　3 棵最简约树的严格合意树,表明新属代表了真盔甲鱼类的最原始类型

Fig. 6　Strict consensus tree of three most parsimonious trees, showing that *Anjiaspis reticularis* represents the most primitive taxon of the Eugaleaspiformes

简字说明 Abbreviations: *A*. *Anjiaspis*, *C*. *Changxingaspis*, *D*. *Dayongaspis*, *E*. *Eugaleaspis*, *H*. *Hanyangaspis*, *M*. *Meishanaspis*, *N*. *Nochelaspis*, *P*. *Pterogonaspis*, *S*. *Sinogaleaspis*, *T*. *Tridensaspis*, *Y*. *Yunnanogaleaspis*

系统发育分析结果表明,新属代表了真盔甲鱼类的最原始类型,同时在新属种中也出现了中背孔前端距离头甲吻缘较远,眶孔前后中长比超过 1.1,松果孔前区长于松果孔后区等与真盔甲鱼属相似的特征。但通过进一步比较,我们发现新属的中背孔、眶孔和松果孔并没有后移的趋势,而是由于吻缘向前较为突出所造成的相对后移,可能是平行进化的结果。另外新的系统发育分析结果表明,浙江"中华盔甲鱼"的中背管不发育可能并不是真盔甲鱼类的原始特征,而是后来退化的结果。

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A NEW GENUS OF EUGALEASPIDS (GALEASPIDA, AGNATHA) FROM THE SILURIAN OF ANJI, ZHEJIANG, CHINA

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Key words Anji, Zhejiang, Silurian, eugaleaspids

Summary

A new genus of the Eugaleaspiformes (Galeaspida), *Anjiaspis* is described in this paper. Fossil materials were discovered from the Maoshan Formation (Wenlockian, Silurian) of Anji county, Zhejiang Province, China.

Galeaspida Tarlo, 1967
Eugaleaspiformes (Liu, 1965) Liu, 1980
***Anjiaspis* gen. nov.**

Etymology After the county of Anji, Zhejiang Province, China, and *aspis* (Gr.) = shield.
Type species *Anjiaspis reticularis* gen. et sp. nov.
Diagnosis As that of the type and only species, *Anjiaspis reticularis* gen. et sp. nov.

***Anjiaspis reticularis* gen. et sp. nov.**
(Figs. 2 ~ 5)

Etymology From *reticularis* = meshy, netlike, reticulate, in reference to the netlike sensory canal system.

Holotype A complete cephalic shield (IVPP V 14332.1).

Referred specimens Two incomplete cephalic shields, with well-preserved sensory canals. IVPP V 14332.2A, B, V 14332.3A, B.

Locality and horizon Anji, Zhejiang Province, southeastern China; Maoshan Formation (Wenlockian).

Diagnosis A small-sized galeaspid with a subtriangular cephalic shield which is broader than long; lateral margin of cephalic shield serrated; corner and inner corner not very developed, short spine in shape; median dorsal opening, drop-like in shape with a pointed anterior end, a blunt posterior end; anterior end of median dorsal opening far behind rostral margin of cephalic shield, posterior end in front of orbital openings; orbital opening round and fairly small, very close to mid-line of cephalic shield and closer to the posterior margin of cephalic shield than to the anterior; pineal opening level with the center of orbital opening; sensory canal system reticulate with 4 longitudinal canals and 8 transverse canals; six pairs of branchial chambers; ornament with evenly-distributed, minute round tubercles.

Comparison and discussion The new genus has a longitudinal oval median dorsal opening and typical eugaleaspid-pattern sensory canal system, and can be referred definitely to the Eugaleaspiformes. It is distinct from the other genera of the Eugaleaspiformes in its fairly small orbital openings which are very close to the mid-line of the cephalic shield. The new form resembles *Meishanaspis lehmani* (Wang, 1991) and '*Sinogaleaspis*' *xikengensis* (Pan and Wang, 1980) in the subtriangular cephalic shield and serrated lateral margin (according to our new observation, the lateral margin of '*S.*' *xikengensis* is also serrated). They differ in that the corner and inner corner

of the new form are very small, short spine-shaped (developed in the other two). Among these three forms, *Anjiaspis reticularis* more closely resembles '*S.*' *xikengensis* in the shape of the median dorsal opening and position of the pineal opening which is level with the centers of the orbital openings (level with the posterior margin of the orbital openings in *Meishanaspis lehmani*). The new form and '*S.*' *xikengensis* have a drop-like median dorsal opening which is situated in front of the orbital openings. They are distinguishable in that the anterior end of the median dorsal opening of '*S.*' *xikengensis* reaches the rostral margin of the cephalic shield, whereas that of the new form is far behind the rostral margin. In *Meishanaspis lehmani*, two ends of the median dorsal opening are pointed, and the posterior end levels with the anterior margin of the orbital openings.

The new genus bears some morphological similarities with the outgroup taxa of the Eugaleaspiformes (e.g. *Dayongaspis hunanensis* Pan et Zeng, 1985), including the serrated lateral margin of cephalic shield, and the orbital openings close to the mid-line of the cephalic shield. These characters are most likely to be plesiomorphic in galeaspids.

Concerning the sensory canal system, there exist striking differences between the new form and the other eugaleaspids. *Anjiaspis* has 4 longitudinal stems and 8 transverse branches linking them on the dorsal side of cephalic shield. Among 4 longitudinal stems, the outer stems are composed of an infraorbital canal and a lateral dorsal canal; the inner stems are composed of an anterior supraorbital canal, a posterior supraorbital canal and a median dorsal canal. But these three canals are joined naturally in the new genus and there is no gap or angle between them. The new genus has 8 median transverse canals which are much more than 3 median transverse canals in *Sinogaleaspis shankouensis* (Pan and Wang, 1980). The distribution of the sensory canal in the new genus mostly matches the pattern of the ancestral vertebrates assumed by Liu (1986).

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References

Bureau of Geology and Mineral Resources of Zhejiang Province (浙江省地质矿产局), 1989. Regional Geology of Zhejiang Province (浙江省区域地质志). Geol Mem (地质专报), **1**(11): 1 ~ 688 (in Chinese with English summary)

Gai Z K (盖志琨), Zhu M (朱敏), Zhao W J (赵文金), 2005. New material of eugaleaspids from the Silurian of Changxing, Zhejiang, China, with a discussion on the Eugaleaspid phylogeny. Vert PalAsiat (古脊椎动物学报), **43**(1): 61 ~ 75 (in Chinese with English summary)

Liu Y H (刘玉海), 1986. The sensory line system of Galeaspida (Agnatha). Vert PalAsiat (古脊椎动物学报), **24**(4): 245 ~ 259 (in Chinese with English summary)

Pan J (潘江), 1986. New discovery of Silurian vertebrates in China. In: Selected papers to memory of Prof. S. H. Yoh (纪念乐森玙教授从事地质科学、教育工作六十年论文选集). Beijing: Geol Publ House. 67 ~ 75 (in Chinese)

Pan J (潘江), Wang S T (王士涛), 1980. New finding of Galeaspiformes in South China. Acta Palaeont Sin (古生物学报), **19**(1): 1 ~ 7 (in Chinese with English summary)

Pan J (潘江), Zeng X Y (曾祥渊), 1985. Dayongaspidae, a new family of Polybranchiaspiformes (Agnatha) from early Silurian of Hunan, China. Vert PalAsiat (古脊椎动物学报), **23**(3): 207 ~ 213 (in Chinese with English summary)

Wang N Z (王念忠), 1991. Two new Silurian galeaspids (jawless craniates) from Zhejiang Province, China, with a discussion of galeaspid-gnathostome relationships. In: Chang M M, Liu Y H, Zhang G R eds. Early vertebrates and related problems of evolutionary biology. Beijing: Science Press. 41 ~ 66

Zhu M (朱敏), 1992. Two new eugaleaspids, with a discussion on eugaleaspid phylogeny. Vert PalAsiat (古脊椎动物学报), **30**(3): 169 ~ 184 (in Chinese with English summary)

Appendix I Characters used for the phylogenetic analysis of the Eugaleaspiforms by Gai et al. (2005)
All characters except Character 4 are unordered

1. Shape of median dorsal opening: (0) round; (1) transverse oval (width > length); (2) longitudinal oval (length > width).
2. Longitudinal oval dorsal opening: (0) not slit-like (length/width < 5); (1) slit-like (length/width > 5).
3. Anterior end of median dorsal opening: (0) subterminal; (1) terminal; (2) far from rostral margin of shield.
4. Posterior end of median dorsal opening: (0) in front of or level with anterior margin of orbital opening; (1) between the centre and anterior margin of orbital opening; (2) between the centre and posterior margin of orbital opening. (ordered)
5. First median transverse canal (mtc_1): (0) present; (1) absent.
6. Third median transverse canal (mtc_3): (0) present; (1) absent.
7. Posterior supraorbital canal (soc_2): (0) absent; (1) present.
8. Ltc_a: (0) present; (1) absent.
9. Ltc_b: (0) present; (1) absent.
10. Ltc_c: (0) present; (1) absent.
11. Ltc_4: (0) present; (1) absent.
12. Median dorsal canal: (0) not developed; (1) developed.
13. Corner: (0) present; (1) absent.
14. Extending direction of corner: (0) projecting laterally; (1) projecting backward.
15. Inner corner: (0) present; (1) absent.
16. Shape of inner corner: (0) broad leaf-shaped; (1) spine-shaped.
17. Ratio between preorbital length and post-orbital length in mid-line larger than 0.9: (0) no; (1) yes.
18. Ratio between preorbital length and post-orbital length in mid-line larger than 1.1: (0) no; (1) yes.
19. Pineal organ: (0) in front of or level with posterior margin of orbital opening; (1) behind posterior margin of orbital opening.
20. Ratio between pre-pineal length and post-pineal length in mid-line of cephalic shield larger than 1.0: (0) no; (1) yes.
21. Rostral process: (0) absent; (1) present.
22. Shape of cephalic shield: (0) nearly triangular; (1) nearly semicircular; (2) nearly oval; (3) nearly trapezoid.
23. Edge of cephalic shield: (0) serrated ; (1) smooth.
24. Position of orbital openings: (0) close to mid-line of cephalic shield; (1) far from mid-line of cephalic shield.

Appendix II Data set with 24 characters for 16 taxa (after Gai et al., 2005)

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	**24**
E. xujiachongensis	2	1	2	2	1	1	1	1	1	1	1	1	0	1	1	?	1	1	1	1	0	1	1	**1**
E. lianhuashanensis	2	1	2	2	?	?	?	?	?	?	?	?	0	1	1	?	1	1	1	1	0	1	1	**1**
E. changi	2	1	2	2	1	1	1	1	1	1	1	1	0	1	1	?	1	0	1	1	0	1	1	**1**
E. xiushanensis	2	1	2	2	1	1	1	1	1	1	1	1	0	1	1	?	0	0	1	1	0	1	1	**1**
P. yuhaii	2	1	2	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	1	0	1	**1**
T. magnoculus	2	1	2	1	?	?	1	?	?	?	?	1	0	0	?	?	0	0	?	0	1	0	1	**1**
N. maeandrine	2	1	2	0	1	1	1	1	1	1	1	1	0	1	0	0	1	0	1	0	0	0	1	**1**
Y. major	2	0	2	0	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	0	0	0	1	**1**
S. shankouensis	2	0	2	1	0	0	1	1	1	1	0	1	0	1	0	1	0	0	0	0	0	0	1	**1**
'*S.*' *xikengensis*	2	0	1	0	?	?	?	?	?	?	?	?	0	1	0	1	0	0	0	0	0	0	0	**1**
'*S.*' *zhejiangensis*	2	0	1	0	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	**1**
M. lehmani	2	0	1	0	1	1	1	0	0	0	0	?	0	1	0	1	0	0	0	0	0	0	0	**1**
C. gui	1	?	0	0	0	1	0	0	0	0	0	0	1	?	0	0	0	0	0	0	0	2	1	**0**
H. guodingshanensis	1	?	0	0	0	1	0	0	0	0	0	0	1	?	0	0	0	0	?	0	0	3	1	**1**
D. hunanensis	0	?	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	?	0	0	0	0	**0**
A. reticularis	**2**	**0**	**2**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**?**	**1**	**0**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**0**

0 = plesiomorphic state; 1,2,3 = apomorphic state; ? = unavailable characters or logical impossibility.

New character and taxon are in bold and underlined.